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## **Energy efficient target tracking mechanism using rotational camera sensor in WMSN**

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### **Abstract**

Wireless Multimedia Sensor Networks (WMSN) have recently gained the attention of the research community due to their wide range of applications like Multimedia Surveillance Sensor Network, Environment monitoring and the advancement of Complementary Metal Oxide Semiconductor (CMOS) cameras. Energy-efficient operations are particularly important in order to extend monitoring over a long period of time. In this paper an energy efficient mechanism Energy Efficient Target Tracking (EETT) is presented in which the target detection capability is increased by means of rotation of camera sensor node in WMSN as it detects any target in its Field of View (FoV) and rotates until the target moves out of CS's FoV. On an average 50.7704% energy efficiency is achieved in EETT.

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**Keywords:** WMSN; Camera sensor; Rotational motion; Target detection; Energy efficiency;

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### **1. Introduction**

Wireless sensor networks (WSN) [1] have drawn the attention of the research community in the last few years, driven by a wealth of theoretical and practical challenges. Recently, the availability of inexpensive hardware such as CMOS cameras and microphones that are able to ubiquitously capture multimedia content from the environment has fostered the development of WMSNs [2,3], i.e., networks of wirelessly

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interconnected devices that allow retrieving video and audio streams, still images, and scalar sensor data. Wireless multimedia sensor networks will not only enhance existing sensor network applications such as tracking, home automation, and environmental monitoring, but they will also enable several new applications such as: Multimedia surveillance sensor networks, Storage of potentially relevant activities, Traffic avoidance, enforcement and control systems, Advanced health care delivery, Automated assistance for the elderly and family monitors, Environmental monitoring etc. Wireless camera sensors can be used in both indoor and outdoor environments, where energy and network infrastructure are not available and where no human intervention is possible. They offer a wider panel of applications whether for environmental, industrial or military monitoring [4]. Most recent studies in WMSN focus on increasing the network lifetime [5]. Target monitoring is an important application of WMSN. Recently, various approaches [6-16] are proposed to maintain the accurate tracking of the targets as well as low energy consumption. Clustering is a fundamental technique to manage the scarce network resources [17-23]. The message complexity of an application can be significantly decreased when it is redesigned on top of a clustered network [24].

This paper presents a mechanism Energy Efficient Target Tracking (EETT) in which after detecting a target in its FoV, the camera sensor (CS) rotates as the target moves within the sensor field or in the area of interest till target is in its FoV and thus the detection probability of any target by the camera sensor increases. We also propose that this technique monitors target in an energy efficient manner.

## 2. Related Work

The mobile object tracking is one of the WMSNs applications. This application consists in locating the mobile target at every step of its progression in the surveillance area. The tracking solutions can be classified in three main categories [25]: naive, predictive based and dynamic clustering. Because of the high cost of the naive technique, it is unreasonable to use such a method in WMSNs where energy is a precious resource.

In the predictive based technique, a predictive model is used to predict the future position of the mobile target. An adapted Kalman Filter is used in [26] to calculate the future sensor utility depending on past data collected. In [27] the authors retrieve the mobility parameters of the target and use an autoregressive model to integrate them and predict the future trajectory. Dynamic clustering [28] is the most used technique in literature. A cluster of nodes is selected at every step of the evolution of the mobile target in the surveillance region. In [24] authors proposed static clustering for object tracking. This cluster ready infrastructure brings simplicity into target tracking and decreases the energy consumption.

The authors in [29] propose a distributed solution based on node collaboration to select the optimal subset of camera sensors that participate in the target location process. SensEye [30] is the first solution that introduces the concept of heterogeneous network. The authors propose three-tier camera sensors; every tier supports a specific task. The first tier assumes target detection and localization while the second one performs target recognition and the last tier assumes target tracking. The authors of [31] also used the concept of heterogeneous networks but for different objectives. Indeed, the activation goal is the event coverage, they used the scalar sensors to determine the event boundary and actuate the necessary camera sensors. The main objective is the elimination of data redundancy. In [5], authors propose a low-cost new solution for tracking a mobile target called Energy Aware Object Tracking (EAOT). It consists of a distributed cooperative algorithm that runs in heterogeneous Wireless Sensor Networks composed of both scalar and multimedia sensors. The scalar sensors (SS) are equipped with a motion detector; their role is to detect the target and then activate the camera sensors (CS) through message exchanges.

In [5] the authors consider the camera sensors are static i.e. they can't rotate. We have improved the performance of WMSN in both target detection capability and energy consumption by considering rotational motion of camera sensor in EETT.

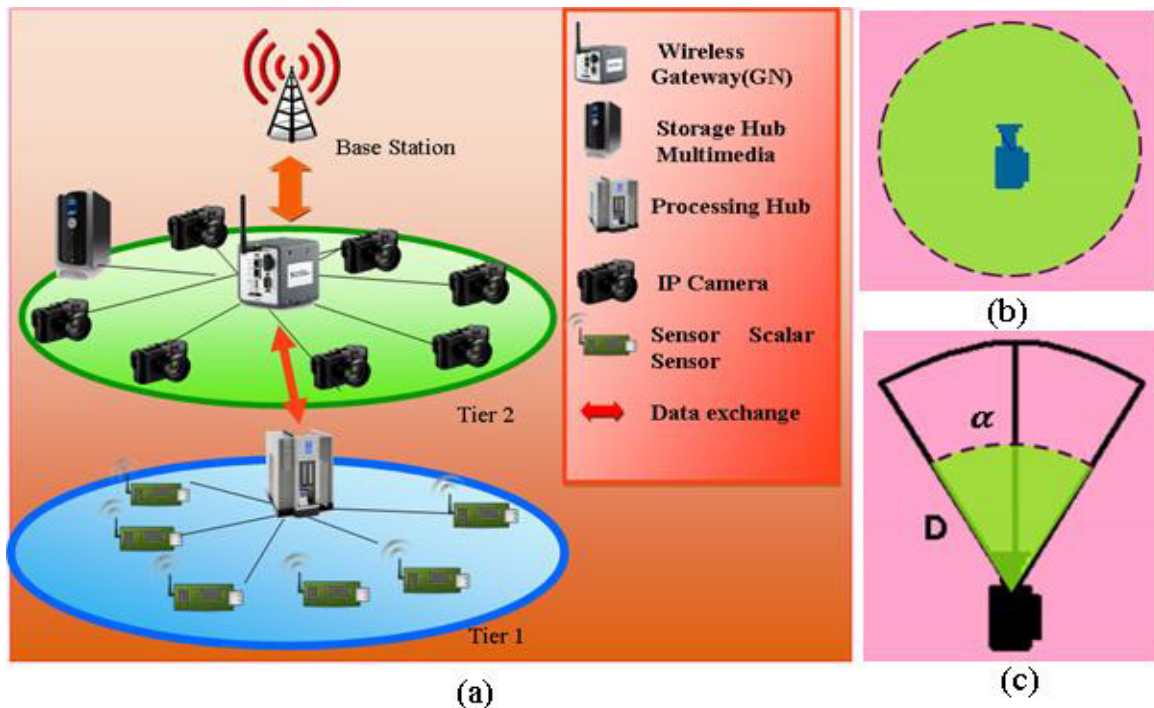


Fig. 1 (a) Multi Tier Heterogeneous Sensor Network Architecture; (b) FoD of CS; (c) FoV of CS ;

### 3. System Model

#### 3.1 Network architecture

We have considered Multi-tier clustered architecture [4, 32] of WMSN in our new proposal as shown in Fig.1(a). In this architecture, the tier 1 consists of scalar sensors that perform simple tasks, like measuring scalar data i.e. light, temperature etc. from surrounding environment, the tier 2 consists of camera sensors that perform more complex tasks such as image capturing or object recognition [33, 34, 35]. Each tier has a central hub or gateway for data processing and communication.

#### 3.2 Cluster formation

In our new approach, clusters are formed statically at the time of network deployment so all the member nodes and their related leader nodes are defined before the tracking algorithm comes into play[24]. This cluster ready infrastructure brings simplicity into target tracking and decreases the energy consumption.

#### 3.3 Kinematic model of rotational camera

In our new proposal we have used rotational camera sensor node. In this subsection we give some definitions.

- Definition 1: Each object located in the Field of Detection (FoD) of SS can be detected. FoD is represented by a circle with radius  $D$  as illustrated in Fig. 1 (b).

- Definition 2: The Camera Sensor (CS) is a wireless multimedia sensor equipped with both motion detector and camera. Each object located in CS's FoV can be visually detected. FoV is a CS's directional of view and it is assumed to be a cone with angle  $\alpha$  and radius  $D$  as illustrated in Fig. 1 (c).

The main difference between SS and CS is not only limited to the services but also to the energy consumption. CS requires more energy to run its cameras compared to SS [5].

The control objective is to maintain the target being tracked in the center of the camera view. In our proposition, we adopt the kinematic model of pan-tilt cameras developed in [36,37] to explain the camera control objective.

### 3.4 Energy model for packet exchange

Heinzelman *et al.* [38] proposed a mechanism for power aware transmission in wireless networks. They used a transceiver model [39] in which the power consumed to transmit a  $k$ -bit message over a distance  $d$  is given by eq.(1),

$$E_t = k \cdot (\epsilon_c + \epsilon_{amp} \cdot d^{pl}) \quad (1)$$

where  $\epsilon_c$  is the energy used by the circuit per bit,  $\epsilon_{amp}$  is the energy used by the amplifier per bit, and  $pl$  is the path loss exponent. The power consumed in receiving  $k$  bits is given by eq.(2),

$$E_r = k \cdot \epsilon_c \quad (2)$$

## 4. Proposed work

In this paper we present an improved performance both in target detection capability and energy consumption over EAOT proposed in [5].

The main objectives of our proposition are :

- To increase the target detection capability.
- To save the energy consumption of network.

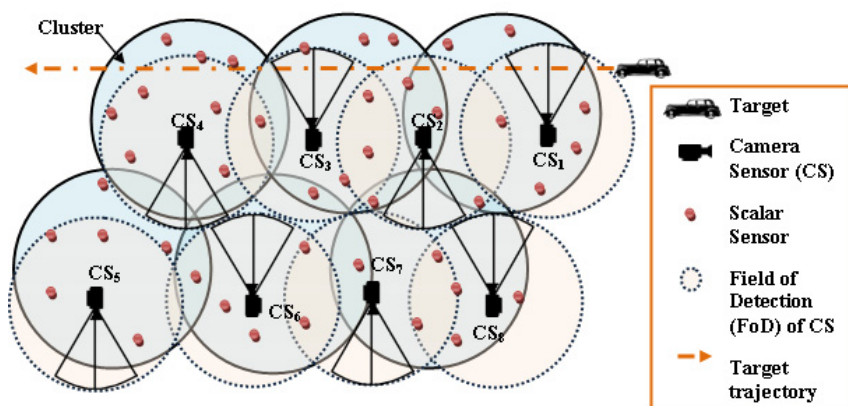


Fig. 2 An example of target monitoring with EETT

In our propose mechanism when a target enters in the area of interest then SS in the border region of clusters detects the target and predict, the target's next location after a predefined time interval, and trigger first camera sensor ( $CS_1$ ) that is within their transmission range and nearest to the target's path by broadcasting DETECTION messages. The first camera sensor becomes active after target enters the area of interest when  $CS_1$  receives at least 2 DETECTION messages that is set as threshold. Then  $CS_1$  starts rotating horizontally as the target moves. When the target is about to move out of FoD of  $CS_1$  then  $CS_1$  passes a control message to the next CS (i.e.  $CS_2$ ), according to the target movement path, to activate  $CS_2$ . When the target moves out of FoD of  $CS_1$ ,  $CS_1$  goes to sleep mode. Now  $CS_2$  rotates with the moving target. When the target is about to move out of FoD of  $CS_2$ , it activates another CS (i.e.  $CS_3$ ) by passing one control message and when target moves out of FoD of  $CS_2$ , it goes to sleep mode. The process continues for target monitoring as shown in Fig. 2.

In this proposition presented here, as the camera sensor rotates with moving target, the target detection capability increases than that of using fixed camera sensors.

We consider here the energy consumption for rotational motion of camera and for passing messages within the network. The energy expenditure for rotational motion of CS is calculated using the following eq. (3).

$$E_r = 0.5 \cdot I_d \cdot \omega^2 \quad (3)$$

where,  $I_d$ =Moment of Inertia of camera module,  $\omega$  =angular velocity

Thus the energy expenditure in the network when  $CS_1$  becomes active is calculated using eq.(4).

$$E_{mc_1} = E_r + E_{act} + 2 \cdot (E_{tx} + E_{rx}) \quad (4)$$

and for activating other camera sensor nodes ( $CS_i$  for  $i = 2 \dots n$ ) each time the energy consumption is calculated using eq. (5).

$$E_{mc_{other}} = E_r + E_{act} + E_{tx} + E_{rx} \quad (5)$$

where,  $E_{act}$ =Activation energy of CS,  $E_{tx}$ =Energy of packet transmission,  $E_{rx}$ =Energy of packet receive. Thus energy consumed by rotating CSs in network is calculated through eq. (4) and eq. (5).

## 5. Simulation result

Table 1: Simulation Parameter

Parameter	Value
Target speed(v)	1.38m/s [5]
Transmission range(d)	30m
Depth of view (R) of CS	20m [5]
Angle of view of CS( $\alpha$ )	60° [5]
Size of message(k)	64Kb [5]
Mass of Camera module	0.04Kg
Length of Camera module	38mm
Width of Camera module	34.5mm
Energy used by circuit/bit( $\epsilon_c$ )	50nJ/bit/m <sup>2</sup> [3]
Energy used by amplifier/bit( $\epsilon_{amp}$ )	0.1nJ/bit/ m <sup>2</sup> [3]
Path Loss(pl)	2 [3]

We have used Matlab7 simulator to simulate our proposed algorithm EETT. We have used 1.3 Mega Pixel HD Serial RS232 Camera Module with Omni Vision CMOS OV9655 sensor [40]. In all scenarios, all the nodes are placed in a rectangle area. The two metrics are used to compare EETT with EAOT: Target detection by CS and energy consumption. All the parameter value for simulation are summarized in Table 1.

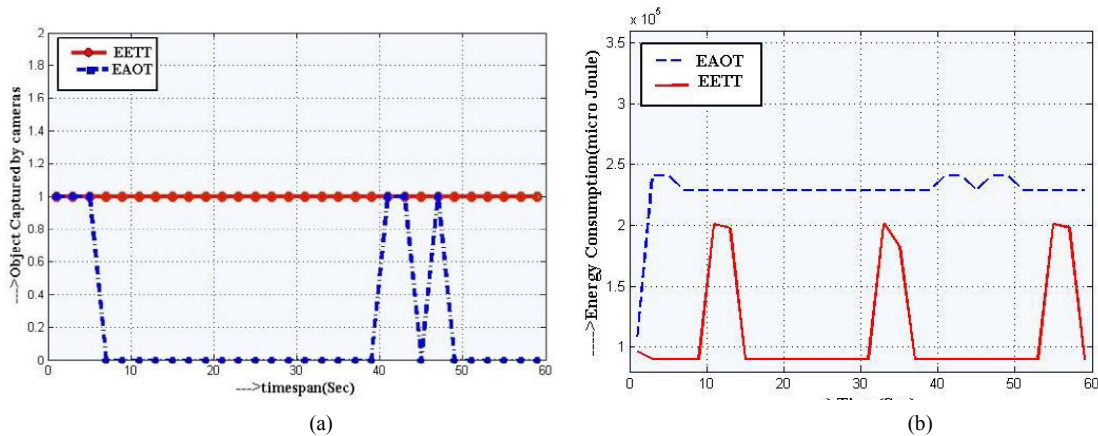


Fig. 3(a)Target detection capability; (b) Energy Consumption (micro Joule) Vs Time (sec) ;

### 5.1 Target detection by CS

We have considered a defined target trajectory. In Fig. 3 (a), If the target is detected by CS then the phenomenon is represented by 1 otherwise 0 i.e. in case of not detection.

Our new proposed solution EETT performs better than EAOT as shown in Fig. 3 (a). Initially in both scenario target is detected by CS. After some time span when the target moved out of detection range of fixed CS, target is not detected by fixed CS but is detected by Rotating CS as it rotates with the moving target. Again when the target comes within the detection range of fixed CS, target is detected by fixed camera. The detection line of EETT takes constantly the value 1 because the target is always detected by rotational CSs as CSs rotate with target movement.

### 5.2 Energy consumption

The energy expenditure is much less in EETT than EAOT as shown in Fig. 3 (b). We have considered here that the target is within the area of interest throughout whole time span. As per EAOT if the target is in area of interest, DETECTION messages are broadcasted by SSs each time CS is activated and if target is within FoV of CS, CS sends LOCALIZATION Message. In EETT, when target enters in the area of interest, to activate the first CS only, DETECTION messages are broadcasted by SSs. When target is about to move out of FoD of CS then CS passes a control message to the next CS to activate it. The energy consumption of network in EETT is calculated using eq.(3),eq.(4) and eq.(5). Spikes in line of energy consumption of EAOT, indicates that the LOCALIZATION message is sent by CS and the straight line indicates only DETECTION messages are received by CS and no LOCALIZATION message is transmitted i.e. the target is not within FoV of CS. Spikes in line of energy consumption of EETT, indicates that the control message is passed between two CSs



when one CS transmits control message to next CS to activate it and straight line indicates no messages are passed by CS, only energy is consumed for rotational motion of CS .

## 6. Conclusion

In this paper energy efficient target tracking mechanism EETT is proposed in which camera sensor rotates with the moving target when the target is in the detection range of that camera sensor. Thus the detection capability of the network increases than that of using static camera sensor as proposed in [5]. As the lifetime of WMSN is a crucial issue, the detection mechanism is presented in an energy efficient way to save the energy consumption of WMSN. On an average the energy consumption for EETT is approximately  $1.1173 \times 10^5 \mu J$  than earlier  $2.2696 \times 10^5 \mu J$  [5].

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